WEED CONTROL TIMING EFFECTS ON CORN YIELD RESPONSE TO NITROGEN

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Introduction

Nitrogen (N) rate guidelines for corn are under continued scrutiny to maximize N use efficiency in order to minimize potential N losses to the environment while maximizing economic returns to growers, especially with significant N fertilizer price increases in recent years. In-season crop stress can potentially affect corn N needs for optimum production. Recently, postemergence weed control has become more common with the availability of glyphosate resistant corn hybrids. Delaying weed control has the potential to alter corn response to applied N because of early-season weed competition for sunlight, soil moisture, and soil N and other nutrients (Davis and Liebman, 2001; Harbur and Owen, 2004; Tollenaar et al., 1994; Evans et al., 2003; Cathcart and Swanton, 2004). Studies indicate that delaying weed control beyond a 10- to 15-cm weed height results in corn grain yield losses of 7 to 20% (Carey and Kells, 1995; Hellwig et al., 2002). The objectives of this research were to determine the effect of weed control timing on the optimum N rate for corn and quantify these N rate differences as weed control timing is delayed.

Materials and Methods

Research to accomplish project objectives was conducted in 2006 and 2007 at the University of Wisconsin Agricultural Research Station at Arlington on a well-drained Plano silt loam soil (fine-silty, mixed, superactive, mesic Typic Argiudoll. A new experimental area was used each year to avoid residual treatment effects. A randomized complete block design in a split-plot arrangement with four replicates was used. The main plot treatment consisted of six N fertilizer (as urea-ammonium nitrate) rates (0, 45, 90, 135, 180, and 225 kg N ha^{-1}) surface broadcast sprayed and incorporated prior to planting. Subplot treatments included four weed control timing treatments (preemerge, 10 cm weed height, 30 cm weed height, and no weed control).

Corn was planted in May in 76 cm rows without starter fertilizer at about 80 000 seeds ha^{-1} with a final recorded pre-grain harvest stand of about 78 000 plants ha^{-1}. Subplot dimensions were 9 m long by 3 m (four 76-cm rows) wide. At the VT stage of corn growth (mid to late July), corn biomass yield was determined by harvesting the above-ground portion of six randomly selected plants from the center two rows of each plot. The whole plant corn samples were weighed, chopped, and subsampled for subsequent dry matter and total N determinations. Corn subsample tissue samples were dried at 60^{o}C, weighed to determine dry matter content, ground to pass a 0.14-mm screen, and analyzed for total N. Corn grain yield was determined by machine harvesting all ears from 18 m of row (two center rows) in October. Corn grain yield is reported at a grain H_2O content of 155 g kg^{-1}.

Data were subjected to an analysis of variance procedure (PROC ANOVA) for the appropriate experimental design (SAS Institute, 2002). Significant treatment differences were evaluated using a protected least significant difference (LSD) test at the 0.05 probability level. Regression analysis (PROC NLIN and PROC REG) was performed using linear, quadratic, quadratic-response plateau, and linear-response plateau methods to determine corn yield response to N fertilizer rate. The regression method with the highest coefficient of determination (R^2) was chosen for individual weed control treatments and years.

Results and Discussion

Nitrogen rate and weed control timing had a significant effect on corn biomass and corn biomass N uptake at the VT (tassel) stage of growth in both years. Corn biomass ranged from 3906 to 8307 kg ha^{-1} in 2006 and from 2925 to 9450 kg ha^{-1} in 2007 (Table 1). Corn biomass N uptake ranged from 23 to 113 kg N ha^{-1} in 2006 and from 22 to 174 kg N ha^{-1} in 2007. Compared with the preemerge weed control treatment, delaying weed control resulted in average corn biomass decreases of 8, 27, and 42% and corn N uptake decreases of 7, 25, and 57% for the 10 cm, 30 cm, and no weed control treatments, respectively. Corn biomass and N uptake increases to applied N at non-limiting N rates averaged 34 and 101%, respectively. However, the increased response to applied N was much greater as weed control timing was delayed. For example, the respective average increase to applied N for the preemerge and no weed control treatment was 18 and 83% for corn biomass and 68 and 229% for N uptake.

The effect of N rate and weed control timing had a significant effect on corn grain yield in both years. Corn grain yield ranged from 4.62 to 14.92 Mg ha^{-1} in 2006 and from 3.61 to 14.74 Mg ha^{-1} in 2007 (Table 2). The significant decrease in corn biomass at VT where weed control was delayed to the 10-cm weed height was not reflected in grain yield. In both years, the effect of weed control timing on average grain yield followed the order: preemerge = 10 cm > 30 cm > no weed control. Compared with the preemerge and 10 cm weed control treatments, grain yields averaged 7% lower in 2006 and 10% lower in 2007 in the 30 cm weed control treatment, and 36% lower in 2006 and 56% lower in 2007 in the no weed control treatment. The greater yield reduction caused by delayed weed control in 2007 may have been the result of higher weed biomass and/or below-normal precipitation during May to July resulting in reduced soil moisture availability. In general, similar trends of N rate and weed control treatments were observed for all plant measurements recorded in this study. In both years, corn grain yield was significantly ($p > 0.0001$) positively correlated with corn biomass and N uptake at the VT stage of growth (r = 0.84 to 0.88).

Corn yield response to N fertilizer rate for each weed control timing treatment and year was further evaluated using regression models (Table 3). The plateau N rate (PNR) and yield at the PNR determined from the regression model and indicates the N rate where no further yield response to N occurred is shown in Table 3. For both years, yield was maximized at N rates below the highest N rate treatment in the preemerge and 10 cm weed control treatments and was fit best using a quadratic-response plateau regression model. For the 30 cm and no weed control treatments, yield response occurred to the highest N rate treatment and was fit best using a linear regression model. The PNR in the preemerge weed control treatment was 126 kg N ha^{-1} in 2006 and 52 kg N ha^{-1} in 2007 which are in the range of PNR values commonly found in corn following soybean crop sequences on silt loam soils in Wisconsin (Bundy et al., 1993). The PNR was 168 kg N ha^{-1} in 2006 and 116 kg N ha^{-1} in 2007 in the 10-cm weed control treatment and $\geq$ 225 kg N ha^{-1} in the 30 cm and no weed control treatments in both years. Respective grain yield increases to N at PNR for the preemerge, 10 cm, 30 cm, and no weed control treatments were 3.72, 3.73, 5.51, and 6.40 Mg ha^{-1} in 2006 and 1.77, 2.30, 3.58, and 4.59 Mg ha^{-1} in 2007.

The amount of additional N fertilizer needed in the delayed or no weed control treatments to achieve the yield obtained at the PNR in the preemerge weed control treatment was calculated using the regression models shown in Table 3 (Table 4). In 2006 and 2007, the respective amount of additional N fertilizer needed (N rate difference) was 21 and 65 kg N ha^{-1} in the 10-cm weed control treatment and 62 and 173 kg N ha^{-1} in the 30-cm weed control treatment. The amount of additional N fertilizer needed to overcome yield losses caused by poor weed control could not be determined in the no weed control treatment in either year, however. These comparisons were also determined based on economic optimum N rates (EONR) where yield response to N rate was adjusted for current N fertilizer and corn grain prices (Table 4). The EONR values were generally lower than PNR values (0 to 11%) and these differences were dependent on year and weed control treatment. However, the additional N fertilizer rate needed in the delayed or no weed control treatments to achieve the yield obtained at the EONR in the preemerge weed control treatment was only 1 to 10 kg N ha^{-1} higher using EONR compared with PNR.

Summary

The amount of additional N fertilizer at the EONR needed to compensate for yield reductions resulting from delayed weed control ranged from 22 to 72 kg N ha^{-1} in the 10-cm weed control treatment and from 69 to 177 kg N ha^{-1} in the 30-cm weed control treatment, and these amounts were greater than the amount of N uptake in weed biomass. Delaying weed control until the 10- and 30-cm weed height resulted in 2-yr average additional N fertilizer costs (\$1.10 kg^{-1} N; \$0.50 lb^{-1} N) of \$49 ha^{-1} and \$135 ha^{-1}, respectively. Additional N fertilizer could not overcome yield reductions where weed control was absent.

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Table 1. Effect of N rate and weed control on corn biomass and N uptake at the VT (tassel) stage of growth, 2006 and 2007.

		Weed control									
Year	N rate	Preemerge	10 cm	30 cm	None	Mean †	Preemerge	10 cm	30 cm	None	Mean ‡
	kg ha^{-1}	-------------- corn biomass at VT, kg ha^{-1} --------------					-------------- corn N uptake at VT, kg ha^{-1} --------------				
2006	0	6594	5869	4105	3906	5118 d §	64	57	44	23	47 c
	45	7667	6985	5557	4774	6246 c	87	74	60	34	64 b
	90	7552	7179	6121	5093	6486 bc	91	92	71	41	74 b
	135	8158	7642	6580	5199	6895 b	113	110	87	50	90 a
	180	7826	7546	7130	5461	6991 ab	103	113	104	51	93 a
	225	8307	7447	8094	6057	7476 a	113	107	104	75	100 a
	Mean ¶	7684 a	7111 b	6265 c	5082 d		95 a	92 a	78 b	46 c	
2007	0	8705	7470	4334	2925	5859 c	109	93	53	22	69 d
	45	8549	7599	5234	4051	6358 bc	127	108	70	34	85 c
	90	9450	7860	7021	4159	7122 ab	151	117	107	42	104 b
	135	9015	8283	6842	5238	7345 a	148	136	115	62	115 b
	180	9154	8824	7661	6139	7945 a	148	159	128	94	132 a
	225	9244	9111	7002	5276	7658 a	174	157	115	73	130 a
	Mean #	9020 a	8191 b	6349 c	4631 d		143 a	128 b	98 c	54 d	

† N rate LSD (0.05): 2006 = 576 and 2007 = 841.

‡ N rate LSD (0.05): 2006 = 10 and 2007 = 14.

§ Within column or row, N rate or weed control means for each year followed by the same letter are not significantly different according to LSD (0.05).

¶ Weed control LSD (0.05): corn biomass = 490 and corn N uptake = 9.

Weed control LSD (0.05): corn biomass = 600 and corn N uptake = 11.

Table 2. Effect of N rate and weed control on corn grain yield at physiological maturity, 2006 and 2007.

Year	N rate	Weed control				
		Preemerge	10 cm	30 cm	None	Mean †
	kg ha^{-1}	-------------------------- corn grain yield, Mg ha^{-1} --------------------------				
2006	0	10.30	10.39	9.12	4.62	8.61 d ‡
	45	12.48	11.88	10.70	6.63	10.42 c
	90	13.71	13.35	12.18	8.34	11.90 b
	135	14.22	13.92	12.26	9.02	12.35 b
	180	13.63	13.77	13.84	9.81	12.76 b
	225	14.20	14.29	14.92	11.48	13.72 a
	Mean §	13.09 a	12.93 a	12.17 b	8.32 c	
2007	0	12.56	11.93	10.39	3.61	9.62 c
	45	14.27	13.04	11.57	4.78	10.92 b
	90	14.58	14.38	13.00	5.19	11.79 ab
	135	14.36	14.08	12.35	6.74	11.88 ab
	180	14.20	13.50	13.28	8.70	12.42 a
	225	14.16	14.74	14.45	7.34	12.67 a
	Mean §	14.02 a	13.61 a	12.51 b	6.06 c	

† N rate LSD (0.05): 2006 = 1.23 and 2007 = 0.99.
‡ Within column or row, N rate or weed control means for each year followed by the same letter are not significantly different according to LSD (0.05).
§ Weed control LSD (0.05): 2006 = 0.69 and 2007 = 0.8

Table 3. Plateau N rate (PNR) and corn grain yield at PNR for four weed control treatments using regression analysis, 2006 and 2007.

Year	Weed control	Regression model †	Method ‡	R^2	PNR	Grain yield at PNR
					kg N ha^{-1}	Mg ha^{-1}
2006	Preemerge	$y = 10.30 + 0.0592x – 0.00024x^2$	QRP	0.98	126	14.02
	10 cm	$y = 10.32 + 0.0443x – 0.00013x^2$	QRP	0.98	168	14.05
	30 cm	$y = 9.42 + 0.0245x$	L	0.97	$\geq$ 225	14.93
	None	$y = 5.13 + 0.0284x$	L	0.97	$\geq$ 225	11.53
2007	Preemerge	$y = 12.55 + 0.0672x – 0.00064x^2$	QRP	0.96	52	14.32
	10 cm	$y = 11.86 + 0.0397x – 0.00017x^2$	QRP	0.81	116	14.16
	30 cm	$y = 10.73 + 0.0159x$	L	0.88	$\geq$ 225	14.31
	None	$y = 3.77 + 0.0204x$	L	0.84	$\geq$ 225	8.36

† x, N rate (kg ha^{-1}); y, grain yield (Mg ha^{-1}).

‡ LRP, linear-response plateau; QRP, quadratic-response plateau; Q, quadratic.

Table 4. Nitrogen rate in the delayed or no weed control treatments to attain the equivalent corn grain yield obtained at the plateau N rate (PNR) and the economic optimum N rate (EONR) in the preemerge weed control treatment, 2006 and 2007.

		Plateau N rate			Economic optimum N rate †		
Year	Weed control	Preemerge grain yield	N rate to attain preemerge yield ‡	N rate difference §	Preemerge grain yield	N rate to attain preemerge yield ‡	N rate difference §
		$Mg\ ha^{-1}$	------------ $kg\ ha^{-1}$ ------------		$Mg\ ha^{-1}$	-------------- $kg\ ha^{-1}$ --------------	
2006	Preemerge §	14.02	126	-	13.92	112	-
	10 cm		147	21		134	22
	30 cm		188	62		184	72
	None		> 225 ¶	-		> 225 ¶	-
2007	Preemerge §	14.32	52	-	14.30	48	-
	10 cm		117	65		117	69
	30 cm		225	173		225	177
	None		> 225 ¶	-		> 225 ¶	-

† EONR based on $1.10 kg^{-1} of N fertilizer ($0.50/lb) and $196.88 Mg^{-1} corn grain ($5.00/bu).

‡ N rate generated for 10 cm, 30 cm, and no weed control treatments from regression models shown in Table 8 where y = grain yield at PNR or EONR for preemerge weed control treatment.

§ The difference in the amount of N needed in the 10 cm, 30 cm, and no weed control treatments compared with the preemerge treatment to attain the yield at PNR or EONR obtained in the preemerge weed control treatment.

¶ Equivalent corn grain yields obtained at the PNR or EONR in the preemerge weed control treatment cannot be attained within the range of N rate treatments.

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